

TECHNICAL REPORT

TM 7001

CR-151230

FEASIBILITY STUDY OF AUTOMATIC CONTROL
OF CREW COMFORT IN THE SHUTTLE
EXTRAVEHICULAR MOBILITY UNIT (EMU)

Job Order 81-107

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AUTOMATIC CONTROL OF CREW COMFORT IN THE
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Prepared By

Lockheed Electronics Company, Inc.
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Houston, Texas

Contract NAS 9-15200

For

CREW SYSTEMS DIVISION

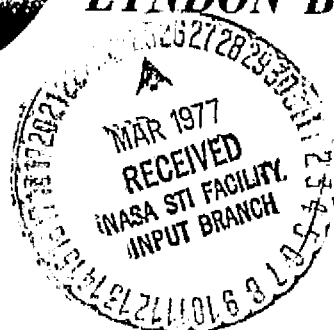


National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER

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February 22, 1977

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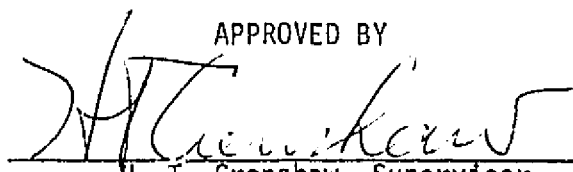
TECHNICAL REPORT
FEASIBILITY STUDY OF AUTOMATIC CONTROL
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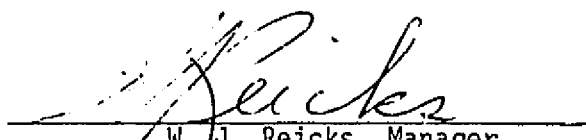
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1. INTRODUCTION

During the Apollo project, crew comfort in the Apollo Extravehicular Mobility Unit (EMU) was maintained by manual manipulation of a valve that controlled the inlet coolant temperature to the liquid cooled garment (LCG). Four inlet temperature selections were possible ranging approximately from 45°F to 80°F. During Skylab, similar comfort control was achieved by manually operating a valve which varied LCG coolant flow rate.

The Shuttle EMU design proposal includes an 11-position manual valve to vary inlet coolant temperature similar to the method used in Apollo. Eleven inlet temperatures would be available for selection vs. the four previously available.

Apollo experience indicates that some training is necessary to enhance the crewman's comfort and optimize his ability to carry a workload. Several tendencies were noted during lunar and Skylab extravehicular activities (EVA's):

- a. Some crewmen precooled themselves in anticipation of a high activity level and left the valve in the valve position selected prior to the activity. A high level of training is needed for such anticipation.
- b. Some crewmen tended to work at rates that were conducive to their comfort at some intermediate cooling level. They would slow down or stop and rest if they became too hot, or they would speed up or hurry to the next activity if they were too cool.
- c. At times, preoccupation with a task would cause a crewman to forget comfort until excessive sweating or fatigue became imminent, and ground controllers would suggest valve changes.

It was proposed that the manual control valve be replaced with an automatic one as a product improvement item for the Shuttle program. The automatic valve proposed would sense the normally measured parameters of LCG inlet coolant temperature and LCG coolant inlet and outlet temperature difference (LCG ΔT) for use in controlling comfort. It was further proposed that if computer

simulations gave encouraging results, that tests would be run on Apollo hardware in which the controller logic was simulated by real-time calculations.

LEC/ASD was tasked with determining the feasibility of such a controller using Program J196 on the 1110 computer and to develop suggested control logic for testing. This memorandum contains the results of that effort.

This concludes the requirements outlined by Action Item 46, Project 3030. The study was conducted by LEC/ASD, Dept. 641-11.

2. DISCUSSION

2.1 CONTROLLER LOGIC

2.1.1 GENERAL

Using Program J196, the 41-node man program (ref. 1), a map of comfort can be plotted at steady state. Heat stored at steady state can be calculated for a grid of metabolic rates and inlet coolant temperatures at a given inlet gas dry bulb temperature, dewpoint temperature, and flow rate, and at a given suit heat leak. LCG coolant temperature difference (LCG ΔT) as calculated at steady state by the program can be plotted vs. metabolic rate for constant inlet coolant temperatures. At each plotted point, the heat stored at steady state can be noted. When the grid is completed, comfort boundaries can be interpolated between the heat storage value as follows:

$$\text{Stored heat at comfort (Btu)} = \frac{\text{Metabolic rate (Btu/hr)} - 278 \pm 65}{13.2}$$

A series of these comfort maps have been plotted. An example of such a study is found in reference 2. An example of this type of plot is shown in figure 1.

From plots such as figure 1, a relationship between inlet coolant temperature and LCG ΔT at steady-state comfort is established (figure 2). It was established by averaging together results from several comfort curves such as in figure 1 and modifying them to get better results while developing the controller logic.

To develop logic for this controller, however, some transient data was needed in order to input to the controller how much variation in LCG ΔT was due to previous inlet temperature adjustments and how much was due to changes in the activity level of the crewman (metabolic rate). Therefore, a controller was simulated on the 41-node man program which adjusted inlet LCG temperature by the heat storage of the body. This would be the ideal controller, but the hardware is not practical. Changes in ΔT vs. changes in inlet temperature

were determined as the simulated man remained at perfect comfort while being stepped from one metabolic rate to another. These points were then plotted and an average curve drawn through the points (fig. 3). This curve represents the expected changes in ΔT for every change in inlet temperature if the controller is perfectly tracking comfort during a transient in metabolic rate.

2.1.2 METHOD 1 - USE OF FIGURE 2

The logic of the controller using figure 2 was developed as follows:

$$\Delta T_{in_1} = K_1 (T_{in}' - \bar{T}_{in_1}) \quad (1)$$

where ΔT_{in_1} = the adjustment signal to the final control element, T_{in} (set point for the inlet coolant temperature to the LCG), calculated from the method using figure 2.

K_1 = The proportional gain constant for the method using figure 2.

T_{in}' = The current inlet temperature to the LCG.

\bar{T}_{in_1} = The inlet temperature at steady state comfort read off figure 2 as a function of the currently measured ΔT .

2.1.3 METHOD 2 - USE OF FIGURE 3

The logic of the controller using figure 3 was as follows:

$$\Delta T_{in_2} = K_2 (\bar{\Delta T}_{in_2}) \quad (2)$$

where

ΔT_{in_2} = The adjustment signal to the final control element T_{in} calculated from the method using figure 2.

K_2 = The proportional gain constant for this method.

$\bar{\Delta T}_{in_2}$ = The changes in the inlet temperature based on figure 3.

$\overline{\Delta T}_{in2}$ is read from figure 3 in the following manner. dT_{in}/dt is calculated (the changes in inlet temperature with time). $d\Delta T/dt$ is read from figure 3 as the expected change in ΔT ($\overline{\Delta\Delta T}$) during the same period of time. Since the same period of time is used, $\overline{\Delta\Delta T}$ is read as a function of ΔT_{in} . The actual change in ΔT ($\Delta\Delta T'$) from the expected $\overline{\Delta\Delta T}$ is then calculated. A calculation of the deviation ($\delta\Delta\Delta T$) of the actual $\Delta\Delta T'$ from the expected $\overline{\Delta\Delta T}$ is made as follows:

$$\delta\Delta\Delta T = \Delta\Delta T' - \overline{\Delta\Delta T} \quad (3)$$

$\delta\Delta\Delta T$ is the main error signal for this method. Error derivative and error integral compensation were also added:

$$\delta\Delta\Delta T = (\Delta\Delta T' - \overline{\Delta\Delta T}) + K_3 \frac{d(\delta\Delta\Delta T)}{dt} + K_4 \int \delta\Delta\Delta T dt \quad (4)$$

where

$$\delta\Delta\Delta T = \Delta\Delta T' - \overline{\Delta\Delta T} \text{ (eq. (3))}.$$

K_3 = the gain constant for error derivative compensation.

$\frac{d(\delta\Delta\Delta T)}{dt}$ = the error derivative compensation.

K_4 = the gain constant for the error integral compensation.

$\delta\Delta\Delta T dt$ = the error integral compensation.

The total error signal $\delta\Delta\Delta T$ is then used on the $\Delta\Delta T/\Delta T$ curve (fig. 3) to determine the adjustment to the final control element, T_{in} , by reading $\overline{\Delta T}_{in2}$. $\overline{\Delta T}_{in2}$ is then applied in eq. (2) to determine the adjustment to the final control element supplied by this method.

2.1.4 FINAL TOTAL CONTROLLER SIGNAL COMBINED FROM FIGURE 2 AND FIGURE 3 METHODS

The two methods described in eqs. (1) and (2) are then combined to give a final calculated value to the final control element, T_{in} :

$$T_{in} = T_{in'} + \left(\frac{\Delta T_{in1} + \Delta T_{in2}}{2} \right)$$

where $T_{in'}$ is the current value of the final control element, the inlet LCG coolant temperature set point.

2.1.5 NEGLECTED CONTROLLER CONSIDERATIONS

Sensor response times, controller deadband, and speed of the final control element were neglected. It should be pointed out that the final control element is the set point for the inlet temperature to the LCG. Another controller would be required to operate the diverter valve bypassing coolant flow around the sublimator in the portable life support system (PLSS) to control the actual LCG inlet temperature. The delay and logic of this controller was neglected in the program and the inlet temperature of the LCG was set instantly to the set point required.

Output differential and integral compensation were attempted in both methods (eqs. 1 and 2). Lack of time prevented the development of gain constants that would improve controller results and these items were not incorporated into the test logic. Error differential and integral compensation in method 1 was never tried for lack of time.

Controller logic was based on Reference 3, pages 6-SERVO-1 through 6-SERVO-20.

2.1.6 PROGRAM CODE AND SAMPLE INPUT

Appendix A shows the program edits used to add the controller logic to Program J196. A nomenclature list is included.

Appendix B shows the input used to develop the necessary calculations from program J196 to do the required pretest predictions.

2.2 CONTROLLER LOGIC VERIFICATION AND PRETEST PREDICTIONS

A 40-hour metabolic profile was run on the J196 program, and values for the gain constants K_1 , K_2 , K_3 and K_4 were varied to obtain optimum controller action. Figures 4 and 5 show the best results that were obtained before an actual hardware test of a simulated controller was run. Figure 4 shows the metabolic profile vs. time. On the same graph, the controller selected inlet temperature and the resulting LCG ΔT are plotted. Figure 5 shows the resulting heat stored vs. time and how it compares to the comfort limits. On the same graph, controller action is shown by a plot of LCG inlet temperature vs. time.

The best values for the controller parameters resulting from these computer runs were as follows:

- a. Values for the inlet temperature vs. LCG ΔT at steady state comfort were taken from figure 2.
- b. Values for $\Delta \Delta T$ vs. ΔT while tracking perfect comfort were taken from figure 3.
- c. Values for K_1 , K_2 , K_3 and K_4 were set at 0.085, 2.6, 0.0000001, and 0.01, respectively.

Pretest predictions of the controller test profile were run using the best controller logic achieved to that point. Metabolic rate levels were proposed to be 15 minutes each of 800, 2000, 400, and 1600 Btu/hr. Results are shown in figure 6. This graph shows heat stored vs. comfort limits. Valve action is shown by plotting inlet LCG temperature for expected test conditions. Recommendations for the test simulated controller included the following:

- a. Set point values for the two curves were set at the figure 2 and 3 values as before.
- b. K_1 , K_2 , K_3 , and K_4 values were set at 0.0952, 2.912, 0.0000001, and 0.01, respectively.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

It can be concluded from computer simulation that crewman comfort can be assured by using automatic control of the inlet temperature of the coolant into the LCG when input to the controller consists of measurements of the LCG inlet temperature and ΔT . Subsequent tests using a facsimile of the control logic developed in the computer program confirmed the feasibility of such a design scheme.

Automatic comfort control has been demonstrated as a desirable product improvement. It is not a design requirement.

3.2 RECOMMENDATIONS

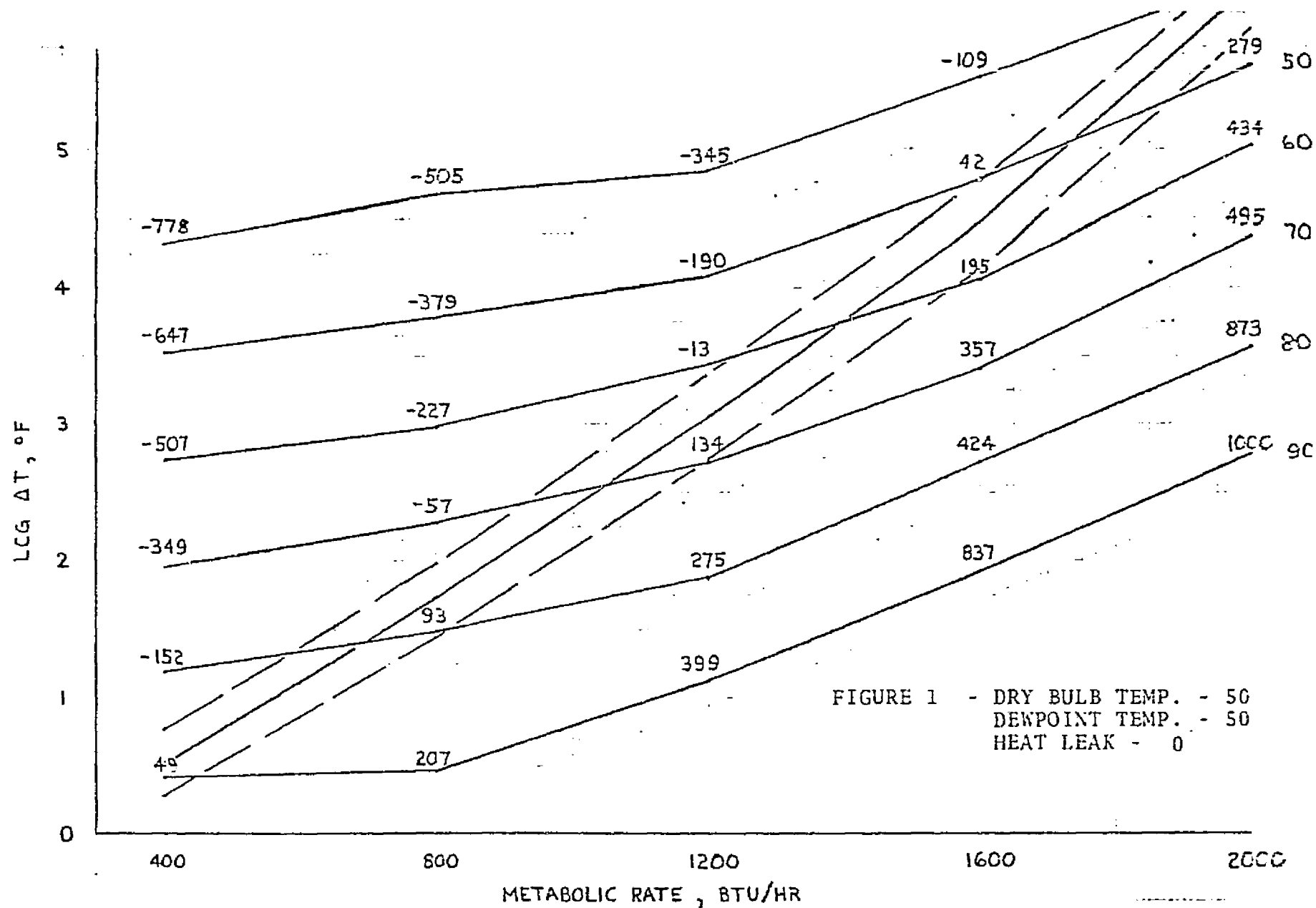
This controller should be fabricated and tested if funds can be made available for product improvement or if some reason is discovered that makes the inclusion of the device mandatory.

Design of the controller should include manual adjustment for shifting the curves from figures 2 and 3 to conform to physical changes such as a heat leak or inlet suit ventilation conditions and to compensate for personal preferences in comfort level. Design provisions should also be included in the PLSS hardware to allow that the controller be bypassed and that manual control of the diverter valve be available.

Final values of K_1 , K_2 , K_3 , and K_4 should be determined by test. Final values for curves 2 and 3 can also be fine-tuned in testing. Output differential and integral compensation should be tested on both methods and error differential and integral compensation tried on method 1.

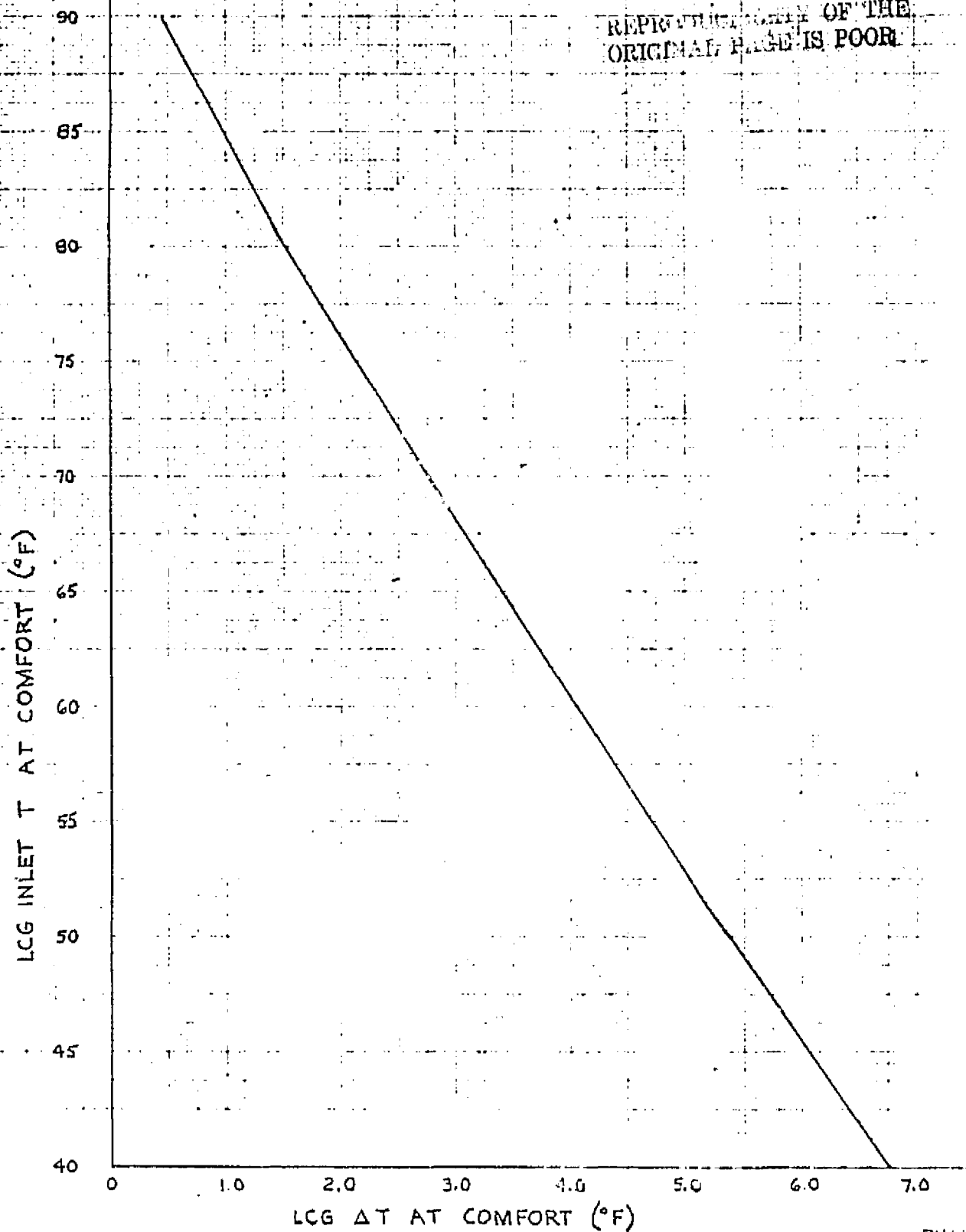
Recommendations for controller logic considerations were taken from reference 3, pages 6-SERVO-1 through 6-SERVO-20.

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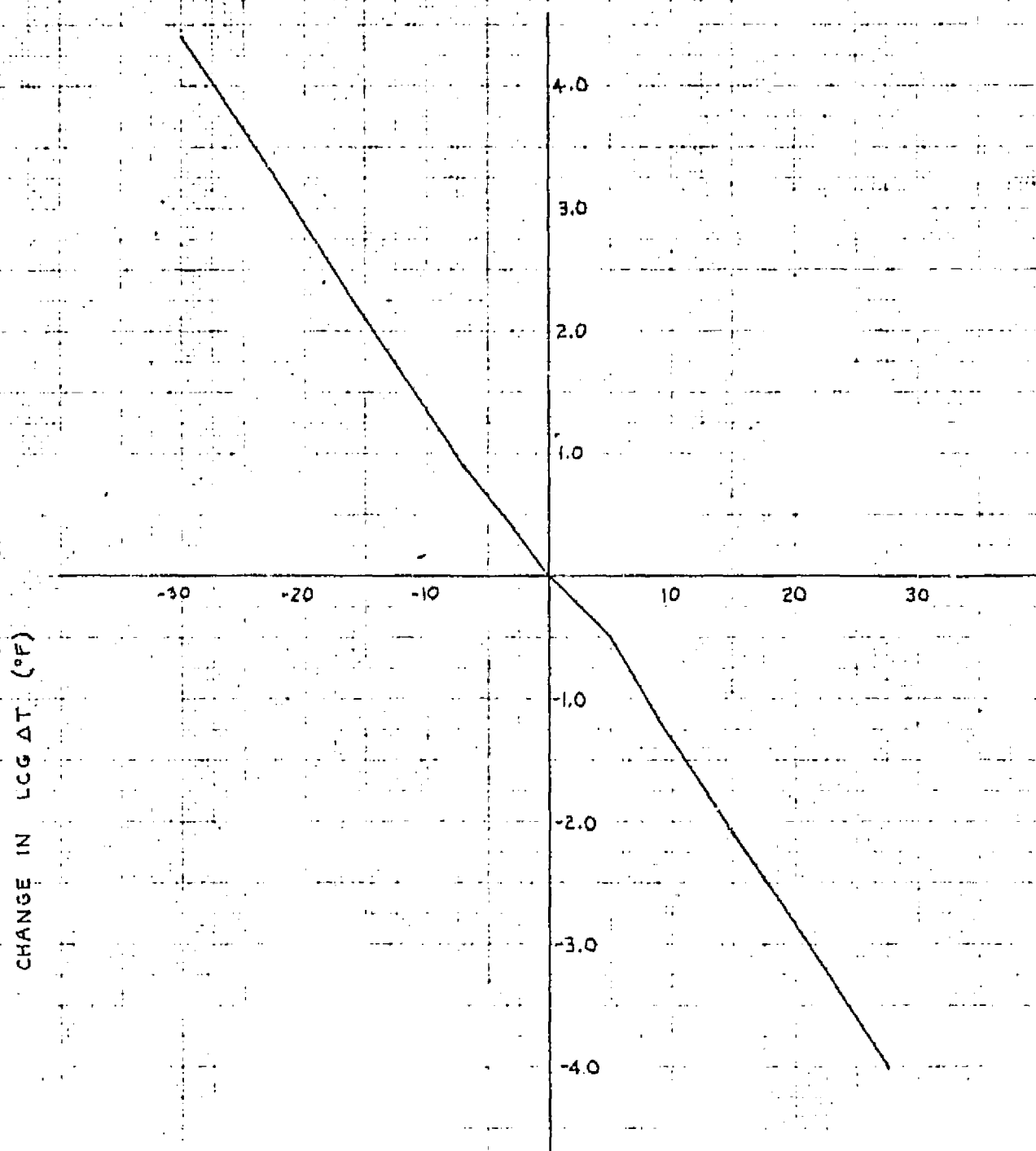
LCG INLET TEMPERATURE VS
 ΔT AT COMFORT

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CHANGE IN LCG ΔT VS CHANGE IN LCG INLET TEMPERATURE WHILE TRACKING COMFORT



CHANGE IN LCG INLET T (°F)

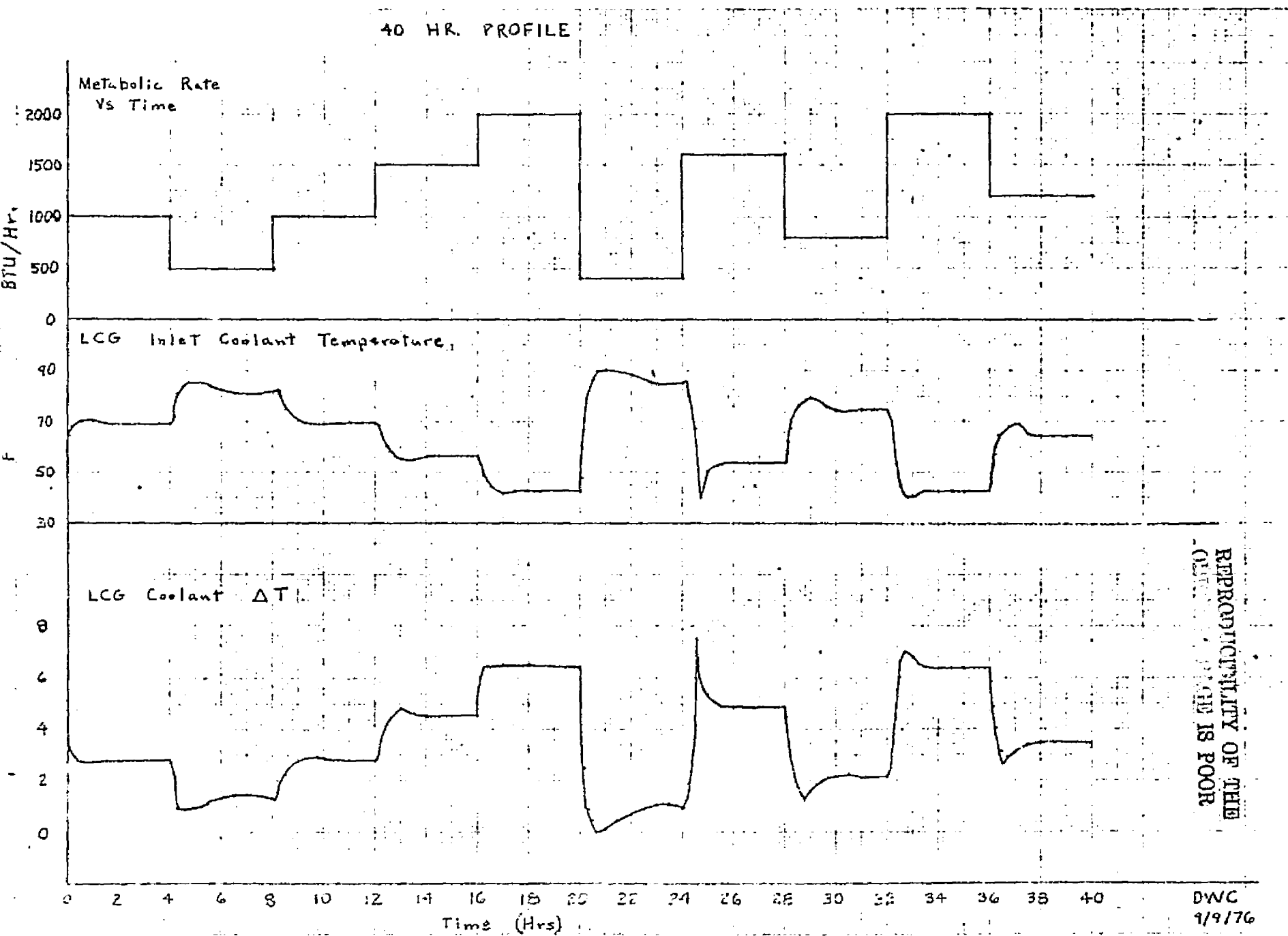


FIGURE 4

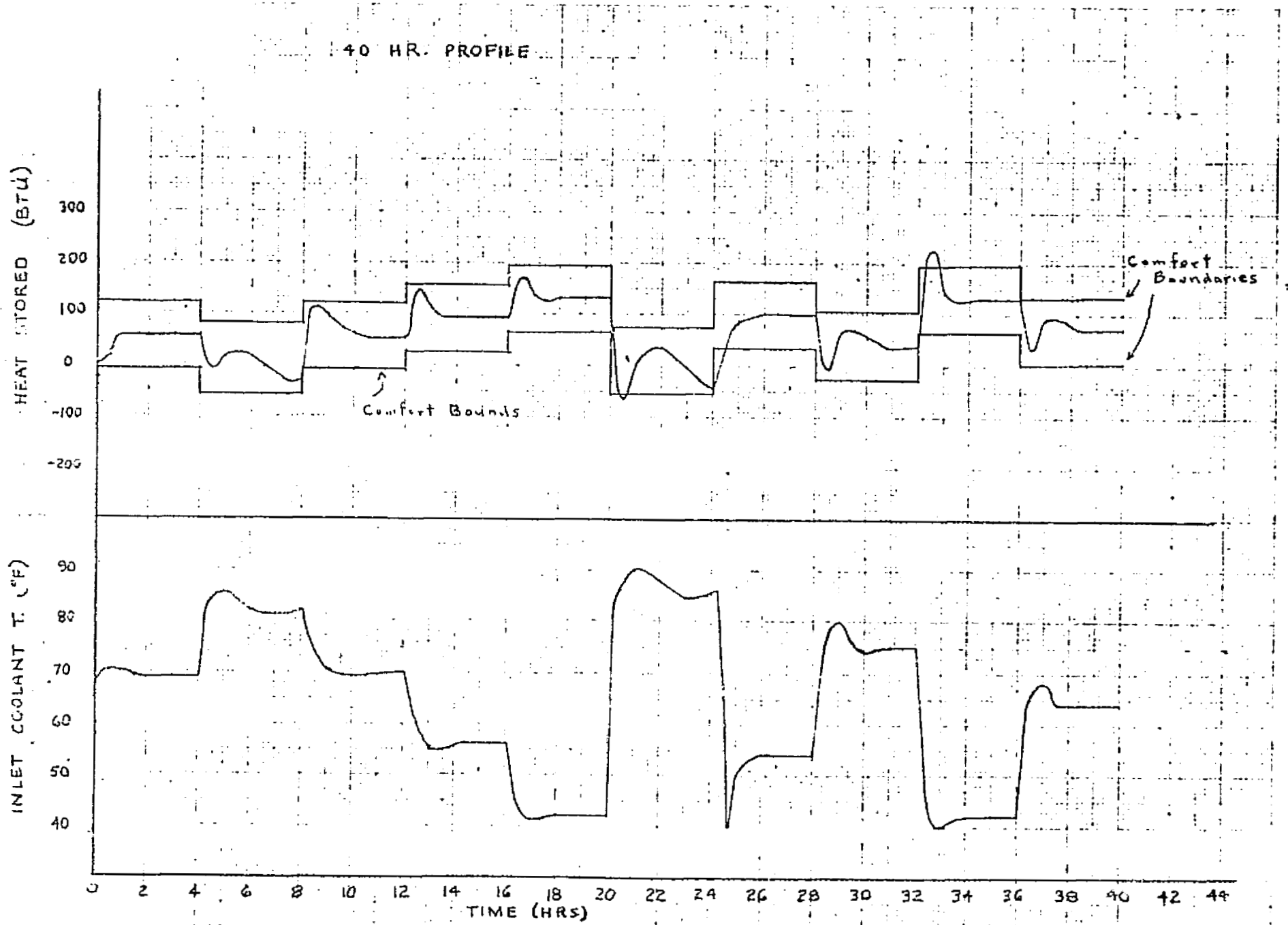


FIGURE 5

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Shuttle EMU Simulated Controller Test

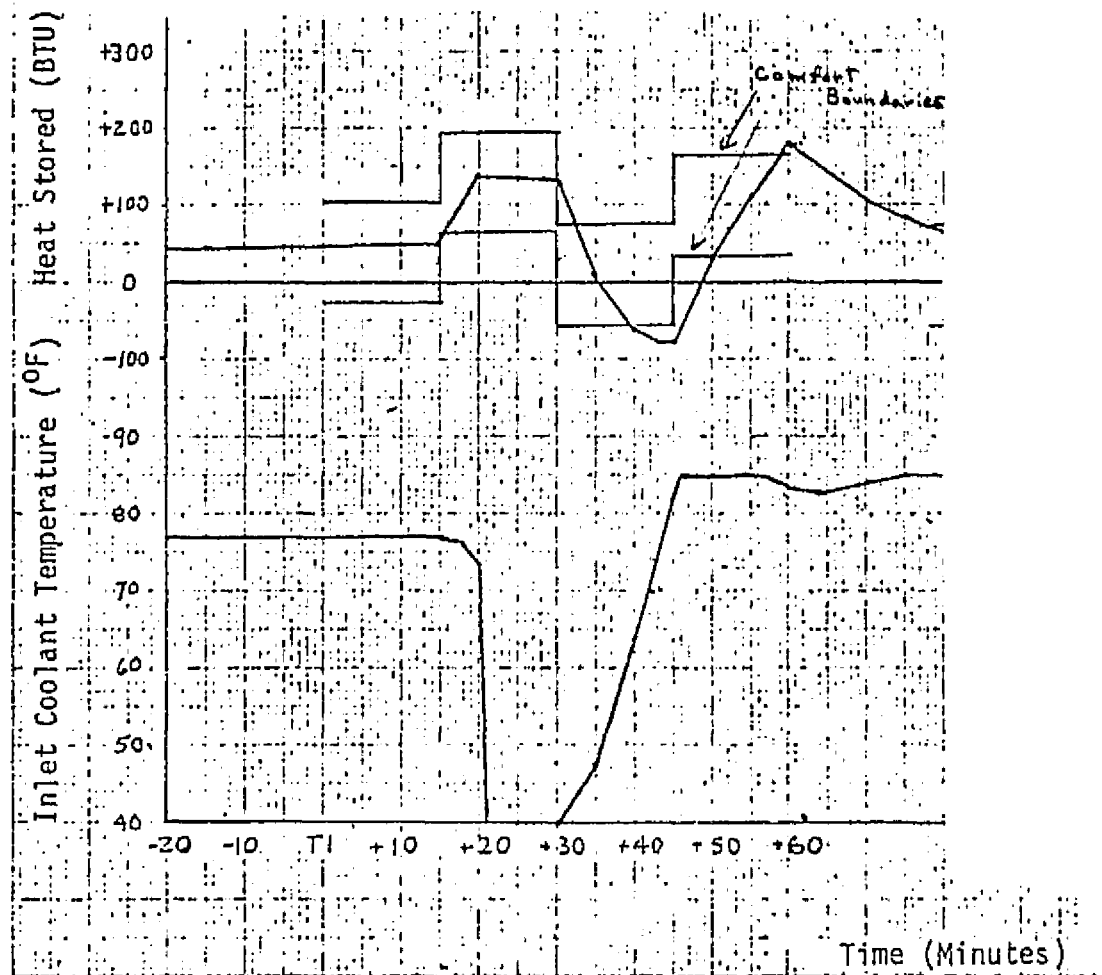


FIGURE 6

REFERENCES

1. Morgan, Lois W., et al: 41-Node Transient Metabolic Man Program, LEC/672-23-030031, May 1970.
2. Cook, D. W.: EMU Comfort Reference Data, TM-675-44-00103, August 25, 1970
3. Barker, R. S., et al: G-189A Generalized Environmental/Thermal Control and Life Support Systems Computer Program, McDonnell Douglas Contract NAS9-10330, September 1971.

APPENDIX A

PROGRAM EDITS TO MODEL THE
PROPOSED CONTROLLER
(NOMENCLATURE LIST IS INCLUDED)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

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0125 74*      CCTW(50), CCMODE(50)
0126 75*      DIMENSION CCOLDL(16), CCOTWI(16)
0127 76*      DIMENSION CCDELT(12), CCCLDP(12)
0127 77*      IF ANY CURVE DIMENSION IS CHANGED CRVS MUST BE REDIMENSIONED
0127 78*      IF NEW CURVES ARE ADDED ACRV, ICRVP, CRVS, AND CRVL SHOULD BE UPDATED
0130 79*      EQUIVALENCE( CRVL(1), CCASHB ), ( CRVL(2), CMODE ), ( CRVL(3), CTGIN ),
0133 80*      1 ( CRVL(4), CTDEW ), ( CRVL(5), CTI ), ( CRVL(6), CPCAP ),
0133 81*      2 ( CRVL(7), CPSC ), ( CRVL(8), CPL2 ), ( CRVL(9), CPM ),
0130 82*      3 ( CRVL(10), CUEFF ), ( CRVL(11), CAF ), ( CRVL(12), CCFMS ),
0130 83*      4 ( CRVL(13), CAKS ), ( CRVL(14), DAKS ), ( CRVL(15), CTDEWC ),
0130 84*      5 ( CRVL(16), CTCAB ), ( CRVL(17), CVCA3 ), ( CRVL(18), CTW )
0131 85*      EQUIVALENCE( ICRVP(1), PCASS ), ( ICRVP(2), PMODE ), ( ICRVP(3), NPTGIN ),
0131 86*      1 ( ICRVP(4), NPTFI ), ( ICRVP(5), NPTWI ), ( ICRVP(6), NPPCAB ),
0131 87*      2 ( ICRVP(7), NPPGC ), ( ICRVP(8), NPP02 ), ( ICRVP(9), NPRM ),
0131 88*      3 ( ICRVP(10), NPPFF ), ( ICRVP(11), NPFF ), ( ICRVP(12), NPCFMS ),
0131 89*      4 ( ICRVP(13), NPAKS ), ( ICRVP(14), OPAKS ), ( ICRVP(15), NPTDWC ),
0131 90*      5 ( ICRVP(16), NPTCAF ), ( ICRVP(17), NPVCAP ), ( ICRVP(18), NPTW )
0132 91*      EQUIVALENCE( CPVS(1,1), CCASHB(1,1) ), ( CPVS(1,11), CCMODE ),
0132 92*      1 ( CPVS(1,12), CCTCIN ), ( CPVS(1,13), CCTDEW ),
0132 93*      2 ( CPVS(1,14), CCTI ), ( CPVS(1,15), CPCAP ),
0132 94*      3 ( CPVS(1,16), CPSC ), ( CPVS(1,17), CPL2 ),
0132 95*      4 ( CPVS(1,18), CUEFF ), ( CPVS(1,19), CPM ),
0132 96*      5 ( CPVS(1,20), CAF ), ( CPVS(1,21), CCFMS ),
0132 97*      6 ( CPVS(1,22), CAKS ), ( CPVS(1,23), DAKS ),
0132 98*      7 ( CPVS(1,24), CTCAB ), ( CPVS(1,25), CTDEWC ),
0132 99*      8 ( CPVS(1,26), CVCA3 ), ( CPVS(1,27), CTW )
0133 100*      DATA( TSET(I), I=1,41 ) / 98.0, 97.5, 97.0, 96.6, 96.8, 98.3, 95.9, 94.4, 96.1,
0133 101*      ., 95.1, 94.1, 93.7, 96.1, 95.1, 94.1, 93.7, 97.6, 96.5,
0133 102*      ., 95.1, 94.5, 97.6, 96.5, 95.1, 94.5, 95.9, 95.7, 95.6,
0133 103*      ., 95.5, 95.9, 95.7, 95.6, 95.5, 95.8, 95.5, 95.7, 95.5,
0133 104*      ., 95.5, 95.5, 95.7, 95.5, 94.5 /
0133 105*      DATA( IC(I), I=1,41 ) / 6.67, 1.488, 0.496, 0.535, 20.9, 34.9, 9.42, 2.69, 1.382,
0133 106*      ., 3.35, 0.644, 0.434, 1.352, 3.35, 0.644, 0.484, 4.4, 10.2,
0133 107*      ., 1.58, 1.192, 4.4, 10.2, 1.58, 1.192, 0.156, 0.0738,
0133 108*      ., 0.0992, 0.184, 0.156, 0.3738, 0.0992, 0.184, 0.2645,
0133 109*      ., 0.0738, 0.148, 0.247, 0.2645, 0.0738, 0.148, 0.247,
0133 110*      ., 4.94 /
0133 111*      DATA( PCFLO(J), J=1,5 ) / .2, .125, .125, .275, .275 /
0133 112*      DATA( NB/71*0., AKI/15.5 /
0133 113*      DATA( CCDELT(J), J=1,12 ) / 0.46, 90.0, 1.51, 20.0, 2.75, 70.0, 4.05, 60.0,
0133 114*      ., 5.37, 50.0, 6.75, 40.0 /
0133 115*      DATA( CCOLDL(J), J=1,16 ) / -4.0, 27.5, -1.2, 9.0, -0.5, 5.0, 0.0, 0.0, 0.4,
0133 116*      ., -3.0, 0.9, -7.0, 2.1, -15.0, 4.4, -30.0 /
0133 117*      DATA( CCOTWI(J), J=1,16 ) / -3.0, 4.4, -15.0, 2.1, -7.0, 0.9, -3.0, 0.4, 0.0,
0133 118*      ., 0.0, 5.0, -0.5, 9.0, -1.2, 27.5, -4.0 /
0133 119*      DATA( DELTA / 20.0 /
0133 120*
0133 121*      C DEFINITION OF BODY SEGMENT TEMPERATURE SUBSCRIPTS
0133 122*      C T(1) = HEAD CORE T(2) = HEAD MUSCLE T(3) = HEAD FAT
0133 123*      C T(4) = HEAD SKIN T(5) = TRUNK CORE T(6) = TRUNK MUSCLE
0133 124*      C T(7) = TRUNK FAT T(8) = TRUNK SKIN T(9) = RIGHT ARM CORE
0133 125*      C T(10) = RIGHT ARM MUSCLE T(11) = RIGHT ARM FAT T(12) = RIGHT ARM SKIN
0133 126*      C T(13) = LEFT ARM CORE T(14) = LEFT ARM MUSCLE T(15) = LEFT ARM FAT
0133 127*      C T(16) = LEFT ARM SKIN T(17) = RIGHT LEG CORE T(18) = RIGHT LEG MUSCLE
0133 128*      C T(19) = RIGHT LEG FAT T(20) = RIGHT LEG SKIN T(21) = LEFT LEG CORE
0133 129*      C T(22) = LEFT LEG MUSCLE T(23) = LEFT LEG FAT T(24) = LEFT LEG SKIN
0133 130*      C T(25) = RIGHT HAND CORE T(26) = RIGHT HAND MUSCLE T(27) = RIGHT HAND FAT

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00302 302* C SO THAT CRANE CAN STEP MORE ACCURATELY
00303 303* CALL DISCON
00304 304* 245 CONTINUE
00305 305* ENDDONX=.TRUE.
00306 306* JT=JT+1
00307 307* XHATAR(JT)=SETI/60.
00308 308* IF(JT.EQ.1)GO TO 247
00309 309* C PUT THE XHAT VALUES IN ASCENDING ORDER
00310 310* CALL ASCEND(XHATAR,JT)
00311 311* 247 CONTINUE
00312 312* XHAT=XHATAR(1)
00313 313* IXH=1
00314 314* PREC=5.
00315 315* IF(ICOND.EQ.0) PREC=3.
00316 316* OLGT=-1.
00317 317* DTIME=DT/60.
00318 318* MIN=3
00319 319* VPPCAB = VPP(TDE,C)
00320 320* SPHCAB=VPPCAB*18/(PCAB*29.)
00321 321* TOTCO2=0.0
00322 322* TOTCO2=3.0
00323 323* TOTWCN=0.0
00324 324* FDOTR=0.0
00325 325* 837 CONTINUE
00326 326* H=DTIME
00327 327* INITL=0
00328 328* HC=H
00329 329* AP=ARI
00330 330* IF(MODE.GT.0) AR=AC
00331 331* IF(MODE-1)21,22,23
00332 332* 21 WRITE(6,117)
00333 333* 117 FORMAT(16X,17HSHIRTSLEEVES MODE/)
00334 334* GO TO 26
00335 335* 22 WRITE(6,118)
00336 336* 118 FORMAT(18X,18HNORMAL SUITED MODE/)
00337 337* GO TO 26
00338 338* 23 IF (MODE.GT.2) GO TO 24
00339 339* EVA = .TRUE.
00340 340* WRITE(6,119)
00341 341* 119 FORMAT(21X, 8HEVA MODE/)
00342 342* GO TO 26
00343 343* 24 WRITE(6,120)
00344 344* 120 FORMAT(13X,27HSUITED WITH HELMET OFF MODE/)
00345 345* 26 IF (IPLOP) WRITE(6,1001)
00346 346* 1001 FORMAT(18X,12HPOST LANDING)
00347 347* IF(.NOT. IPLOP) GO TO 1010
00348 348* WRITE(6,1702)PLAS,TATH,VOLCAB,POZA,PNZA,CPA,NUMEN,PA,AREAW,
00349 349* *TDE=AC,CFMC
00350 350* 170. * FORMAT(
00351 351* 1 * ATMOSPHERIC GAS CONSTANT, LBF-FT/(LBM-DEG R)-----,F9.3/
00352 352* 2 * DRYBULB TEMP. OF ATMOSPHERE, DEG.F-----,F9.3/
00353 353* 3 * VOLUME OF CABIN, CU FT-----,F9.3/
00354 354* 4 * ATMOSPHERIC OXYGEN PARTIAL PRESSURE, PSIA-----,F9.3/
00355 355* 5 * ATMOSPHERIC NITROGEN PARTIAL PRESSURE, PSIA-----,F9.3/
00356 356* 6 * SPECIFIC HEAT OF ATMOSPHERE, BTU/(LBM-DEG F)-----,F9.3/
00357 357* 7 * NUMBER OF MEN-----,I9/
00358 358* 8 * ATMOSPHERIC PRESSURE, PSIA-----,F9.3/
00359 359* * CABIN WALL AREA, SQ FT-----,F9.3/

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[illegible]

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1002 587* WRITE(6,99)
1004 588* MODEG=MODE
1005 589* MODE=MODEG
1006 590* EVA=.FALSE.
1007 591* GO TO 887
1010 592* 888 CONTINUE
1011 593* IF (CTGIN) CALL LAGIN (1,CCTGIN,NPTGIN,2,TIME,TGIN)
1012 594* IF (CTDEW) CALL LAGIN (2,CCTDEW,NPTDEW,2,TIME,TDEW)
1013 595* IF (CTWI) CALL LAGIN (3,CCTWI,NPTWI,2,TIME,TWI)
1014 596* IF (CPCAB) CALL LAGIN (4,CCPCAB,NPPCAB,2,TIME,PCAB)
1015 597* IF (CPGC) CALL LAGIN (5,CCPGC,NPPGC,2,TIME,PG)
1016 598* IF (CP02) CALL LAGIN (6,CCP02,NPP02,2,TIME,P02)
1017 599* IF (CRM) CALL LAGIN (7,CCRM,NPRM,2,TIME,RM)
1018 600* IF (CUEFF) CALL LAGIN (8,CCUEFF,NPU EFF,2,TIME,UEFF)
1019 601* IF (.NOT. CWF) GO TO 380
1020 602* WFOLO=WF
1021 603* CALL LAGIN(9,CCWF,NPWF,2,TIME,WF)
1022 604* WDOT1=WDOT1*WF/WFOLO
1023 605* 380 CONTINUE
1024 606* IF (CCFMS) CALL LAGIN (10,CCCFMS,NPCFMS,2,TIME,CFMS)
1025 607* IF (.NOT. CAKS) GO TO 725
1026 608* CALL LAGIN (11,CCAKS,NPAKS,2,TIME,AKST)
1027 609* DO 725 I=1,10
1028 610* AKS(I)=AKST
1029 611* 725 CONTINUE
1030 612* IF (DAKS) CALL LAGIN(12,DDAKS,UPAKS,2,TIME,AKS(I))
1031 613* 730 IF (.NOT. COASRB) GO TO 400
1032 614* DO 726 I=1,10
1033 615* CALL LAGIN(13,CCQASR(1,I),NPQASR,2,TIME,QASRB(I))
1034 616* 726 CONTINUE
1035 617* 430 CONTINUE
1036 618* IF (TRAN .OR. IQ.EQ. 0) GO TO 430
1037 619* CALL THATRX
1038 620* 430 CONTINUE
1039 621* DELTAT=DELDT
1040 622* WILDLT=WOLDLT
1041 623* CALL SUIT
1042 624* DELTAT=TWO-TWI
1043 625* TWI=TWI
1044 626* OLDLT=DELTAT-DELTAT1
1045 627* EDOLDLT=EDOLDLT*H/H0
1046 628* WOLDLT=OLDLT-EDOLDLT
1047 629* EDOLDLT=EDOLDLT*(OLDLT-WILDLT*H/H0)/H
1048 630* TOLDLT=TOLDLT+EDOLDLT*H
1049 631* WOLDLT=WOLDLT+EDOLDLT*H
1050 632* CALL LAGIN(9,CCOLDLT,8,2,DELTAT,TWI)
1051 633* TWI=TWI+2.6*DT*TWI
1052 634* CALL LAGIN(9,CCDELT,8,2,DELTAT,TW12)
1053 635* TW12=TWI1+0.035*(TW12-TW11)
1054 636* TWI=(TWI+TW12)/2.0
1055 637* IF (TWI.GT.93.0) TWI=93.0
1056 638* IF (TWI.LT.40.0) TWI=40.0
1057 639* DT=I-TW11
1058 640* CALL LAGIN(10,CCDTWI,8,2,DTWI,EDOLDLT)
1059 641* H0=H
1060 642* CO2RATE= (0.001708-(100-0.707)/0.293*0.000123))*RM
1061 643* CO2RAT=CO2RATE*44.0/32.0*RL

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REPRODUCIBILITY OF THE
 ORIGINAL PAGE IS POOR

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1244 701* KOUNTN = KOUNTN+24
1245 702*
01247 703* 704 IF (IMPAIP .AND. OSTOR .GT. 1000) GO TO 706
01250 704* CO TO 705
01252 705* 706 IF (KOUNTN .GT. 24) GO TO 709
01254 706* WRITE (6,632)
1255 707* WRITE (6,601)
1257 708* CO TO 714
01261 709* 709 WRITE (6,99)
01263 710* WRITE (6,601)
01265 711* 714 WRITE (6,608)
1266 712* TIRM=.TRUE.
1267 713* GO TO 14
01270 714* 705 CONTINUE
01272 715* WRITE (6,113) PTIM,TGOUTS,SHSO,T(1),T(72),TISAV,TOSAV,QTSUIT,SOUG,
01274 716* ICEVAP,TOTL,STORAT,OSHTV,OSTOR
01276 717* SUBOT = SUBOUT - SUBIN
01278 718* UTPP=760.0/14.7*PH2OSO
01313 719* TDEWOT=DEWPT (OTPR)
01314 720* UTPPI=PG*SHSO*32.0/18.0*760.0/14.7
01315 721* TDWOT1=DEWPT (OTPRI)
01316 722* SATPRS=VPP(TGOUTS)
01317 723* HELPHM=PH2OSO/SATPRS
1317 724* IF (LCG) WRITE (6,999) T*1,T*2,DELTAT,IDEW,TGIN,TOTCO2,TOTCO2,TOTWCN,
1318 725* FDNTR,RM,W
1319 726* NAMELIST/NO1/T*1,DLTAT1,DLDT,WDLDLT,DT*1,EDLDLT,TW12
01341 727* WRITE (6,901)
01343 728* IF (MODE .EQ. 1 .OR. MODE .EQ. 2) WRITE (6,2032) HCO2MH
01345 729* IF (IPLOP) WRITE (6,1033) TCAD,TDEWC,CO2MMH
01347 730* 1655 FORMAT(15H CABIN TEMP =,F7.2, 6H DEG F,18H DEWPOINT TEMP =,
01349 731* 1 F7.2, 6H DEG F,17H CO2 PRESSURE =,F7.2, 6H MM HG/)
01351 732* OLATIR = OLAT(1) + OLAT(5) + OLAT(2) + OLAT(3) + OLAT(6)
01353 733* IF (IPLOP) GO TO 1605
01355 734* IF (KOUNTN .EQ. 48) GO TO 1606
01357 735* KOUNTN = KOUNTN + 3
01359 736* GO TO 1608
01361 737* 1630 WRITE (6,112)
01363 738* KOUNTN = 0
01365 739* CO TO 1608
01367 740* 1605 IF (KOUNTN .EQ. 48) GO TO 1607
01369 741* KOUNTN = KOUNTN + 4
01371 742* GO TO 1608
01373 743* 1607 WRITE (6,112)
01375 744* KOUNTN = 0
01377 745* 1606 IF (TRAN) GO TO 490
01379 746* ASSIGN 14 TO IJM
01381 747* ASSIGN 12 TO IJMP
01383 748* GO TO 780
01385 749* 49. CONTINUE
01387 750* IF (JT .EQ. 0 .OR. ENDONX) GO TO 915
01389 751* IXH=IXH+1
01391 752* IF (IXH .LE. JT) GO TO 910
01393 753* JT=0
01395 754* GO TO 915
01397 755* 91. ENDONX=.TRUE.
01399 756* XHAT=XHATAR(IXH)
01401 757* 915 CONTINUE
01403 758* C CHECK IF CRANE HAS SET THE FLAG ENDONX TO FALSE TO INDICATE THE

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NOMENCLATURE OF VARIABLES APPEARING IN CONTROLLER EDITS

<u>Program name</u>	<u>Document engineering symbol</u>	<u>Description</u>
CCDELT	Figure 2	Curve of LCG ΔT vs. inlet temperature at comfort (both in $^{\circ}\text{F}$).
CCDLDL	Figure 3	Curve of change in LCG ΔT vs. change in LCG inlet temperature while tracking perfect comfort with the changes in inlet temperature as the dependent variable (all $^{\circ}\text{F}$).
CCDLDP	not currently used.	
CCDTWI	Figure 3	Curve of change in LCG ΔT vs. change in LCG inlet temperature while tracking perfect comfort with the change in LCG ΔT as the dependent variable (all $^{\circ}\text{F}$).
DELTAT	LCG ΔT	Difference in the liquid cooled garment inlet and outlet coolant temperature ($^{\circ}\text{F}$).
DDLDT	$d\Delta T/dt$	Error differential compensation ($^{\circ}\text{F}/\text{hr}$).
DLDLT	$\Delta\Delta T$ or $d\Delta T/dt$	Change in LCG ΔT with respect to time. (Time cancels out on the $\Delta\Delta T$ vs. ΔT curve) ¹ ($^{\circ}\text{F}/\text{hr}$ or $^{\circ}\text{F}$).
DLTAT1	-----	Difference in the liquid cooled garment inlet and outlet coolant temperatures calculated in previous time step ($^{\circ}\text{F}$).
DTWI (first appearance)	ΔT_{in2}	The adjustment signal to the final control element using method 2, figure 3, eq. (2).
DTWI (second appearance)	-----	Final complete adjustment signal to the final control element, T_{in} .

NOMENCLATURE OF VARIABLES APPEARING IN CONTROLLER EDITS (Continued)

<u>Program name</u>	<u>Document engineering symbol</u>	<u>Description</u>
DTWI (second appearance)	dT_{in}/dt	Changes in LCG inlet temperature between current time increment and last ($^{\circ}\text{F/hr}$).
EDLDT	$\overline{\Delta\Delta T}$	Expected change in LCG ΔT ($d\Delta T/dt$) that would accompany a change in LCG inlet temperature if perfect comfort were being tracked ($^{\circ}\text{F/hr}$).
H	dt	Current time increment (hr).
HO	-----	Previous time increment (hr).
RDLDT	$\int \delta\Delta T \, dt$	Summation of $\delta\Delta T$ times the time increment ($^{\circ}\text{F/hr}$).
TWI (first appearance)	-----	New position of the final control element as calculated by method 2, figure 3, eq. (2) ($^{\circ}\text{F}$).
TWI (second appearance)	T_{in}	New position of the final control element ($^{\circ}\text{F}$).
TWI1	-----	Position of the final control element at the previous time increment ($^{\circ}\text{F}$).
TWI2	-----	Position of the final control element as calculated by method 1, figure 2, eq. (1).
WDLDT	$\delta\Delta T$	Deviation of the actual change in LCG ΔT from the expected change in LCG ΔT
WILDT	-----	WDLDT at the previous time increment.

APPENDIX B

INPUT TO PROGRAM J196 TO BRING ABOUT
THE NECESSARY CONTROLLER PRETEST PREDICTIONS
AND EVALUATIONS

REL,ULL DATA

ELT007 RL71-3 09/18/76 08:20:50 (1,2)

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00001 000 $INPUT
00002 000 MODE=2,
00003 NEW 002 MODE=1,
00004 000 RM=1200.,
00005 NEW 002 RM=1000.0,
00006 000 DEFF=0.,
00007 000 AC=19.5,
00008 NEW 002 AP1=19.5,
00009 -01 000 G=C.,
00010 000 ALUG=0.0141,
00011 000 AKUG=.046,
00012 000 EUG=0.9,
00013 001 ACSUIT=9.22,2.91,2.91,6.38,6.38,0.77,0.77,1.19,1.19,1.85,
00014 001 ARSUIT=7.34,2.22,2.32,5.07,5.07,0.62,0.62,0.96,0.96,1.47,
00015 001 ALS=9*.0078,.021,
00016 001 AKS=9*.000383,.02155,
00017 001 EOS=9*0.91,.62,
00018 001 ETS=10*0.90,
00019 001 WS=15.60,4.89,4.89,10.82,10.82,1.22,1.22,1.95,1.95,2.75,
00020 001 CPS=9*0.22,0.30,
00021 000 GASKE=10*308.,
00022 NEW 002 GASRB=10*120.0,
00023 000 VF=0.0,
00024 000 VOLHMT=0.1968,
00025 000 CFMS=6.,
00026 NEW 002 CFMS=5.90,
00027 000 TGIN=80.,
00028 NEW 002 TGIN=45.0,
00029 000 TDE=50.,
00030 NEW 002 TDE=43.0,
00031 000 CPG=0.22,
00032 000 PG=3.85,
00033 NEW 002 PG=4.0,
00034 000 PG2=3.85,
00035 NEW 002 PG2=4.0,
00036 NEW 002 LCG=7,
00037 -01 000 WF=240.,
00038 000 TWI=40.,
00039 NEW 002 TWI=72.,
00040 000 CPW=1.0,
00041 000 UAG=43.5,
00042 000 DT=0.05,
00043 000 PRINTI=5.0,
00044 000 SETI=600.,
00045 NEW 002 SETI=240.0,
00046 NEW 002 MCASES=20.0,
00047 NEW 002 STLPE=.TRUE.,
00048 NEW 002 RM=800.0,
00049 NEW 002 TWI=75.0,
00050 NEW 002 PRINTI=1.0,
00051 000 SEND
00052 NEW 002 $INPUT
00053 NEW 002 RM=500.0,
00054 NEW 002 SETI=15.0,
00055 NEW 002 RM=800.0,

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L00056 NEW 002 $END
L00057 NEW 002 $INPUT
L00058 NEW 002 RM=1000.0,
L00059 NEW 002 SETI=45.0,
L00060 NEW 002 SETI=30.0,
L00061 NEW 002 RM=2000.0,
L00062 NEW 002 $END
L00063 NEW 002 $INPUT
L00064 NEW 002 RM=1500.0,
L00065 NEW 002 SETI=720.0,
L00066 NEW 002 SETI=45.0,
L00067 NEW 002 RM=400.0,
L00068 NEW 002 $END
L00069 NEW 002 $INPUT
L00070 NEW 002 RM=2000.0,
L00071 NEW 002 SETI=960.0,
L00072 NEW 002 SETI=60.0,
L00073 NEW 002 RM=1600.0,
L00074 NEW 002 $END
L00075 -15 000 $PHD,B

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END ELT.

PLP
 PUR 0026-09/18-08:20